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Collaborative Research: Dynamics at the Base of a Pseudotachylyte-bearing Fault System

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Principal Investigator: Johnson, Scott E.
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Johnson, Scott - Principal Investigator
Title:
Collaborative Research: Dynamics at the Base of a Pseudotachylyte-bearing Fault System

Project Participants

Senior Personnel

Name: Johnson, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Koons, Peter
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: West Jr., David
Worked for more than 160 Hours: Yes
Contribution to Project:
David West is our primary collaborator on this proposal, having submitted a collaborative proposal (0810033) through Middlebury College.

Post-doc

Graduate Student

Name: Price, Nancy
Worked for more than 160 Hours: Yes
Contribution to Project:
Nancy is a PhD student conducting her dissertation work in the Norumbega Fault System on topics defined in this proposal.

Name: Marsh, Jeffrey
Worked for more than 160 Hours: No
Contribution to Project:
Jeff is one of Johnson's PhD students, and he has participated in this project by conducting some preliminary numerical analyses of how the kinematic vorticity number determined from mylonites is affected by strain localization at porphyroclast boundaries.

Name: Roy, Samuel
Worked for more than 160 Hours: Yes
Contribution to Project:
Sam is one of Johnson's MS students, and he has participated in this project by conducting some preliminary numerical analyses of the thermal field around faults is affected by transient fluid flow.

Name: Song, Won Joon
Worked for more than 160 Hours: Yes
Contribution to Project:
Won Joon is a PhD student working with the PI on EBSD and computational aspects of the project, wiht special emphasis on the seismic anisotropy of major faults and shear zones.

Name: Frieman, Benjamin

Worked for more than 160 Hours: No

Contribution to Project:
Ben is a graduate student helping with the field and EBSD components of the project.

Undergraduate Student

Name: Lenferink, Hendrik

Worked for more than 160 Hours: Yes

Contribution to Project:
Hendrik completed his Senior Thesis on the topic of kinematic vorticity in these rocks. His work was partly supported by this grant.

Name: Ryan, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:
Patrick is an undergraduate student helping with sample preparation and EBSD analyses of quartz microstructures

Technician, Programmer

Other Participant

Name: Beane, Rachel

Worked for more than 160 Hours: No

Contribution to Project:
Rachel maintains teh SEM-EBSD system at Bowdoin College, which we are making some use of in the early stages of this project. We are installing our our own SEM-EBSD system here at UMaine in April of 2009. Rachel is teh external member on the PhD student's (Nancy Price)dissertation committee.

Name: Seaman, Sheila

Worked for more than 160 Hours: No

Contribution to Project:
Sheila runs the FTIR lab at the University of Massachusetts, Amherst. The PhD student (Nancy Price) working under this award has developed a collaboration with Sheila in order to characterize the H2O in the rocks.

Research Experience for Undergraduates

Organizational Partners

Middlebury College

This is a collaborative proposal with Dave West at Middlebury College.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

The PIs and other faculty/technical participants were actively involved in helping the students formulate their thesis/project goals. They spent a lot of time in the field with the students and worked with them in the microstructural, SEM and microprobe analyses among other

activities.

PhD student Nancy Price completed her degree in May, 2012 (Price, 2012). She collected >200 samples over three field seasons and investigated microstructural relationships within these samples. Among other things, she has spent a considerable amount of time completing SEM-EBSD, electron microprobe, CL, XRD, and FTIR work during these investigations. Nancy also co-organized and co-executed a field trip for a New England Intercollegiate Geological field conference and led a collaborative effort to create the field trip guide chapter based in part on her research (Price et al., 2010).

Graduate student Sam Roy conducted some preliminary numerical analyses of how the thermal field around faults is affected by transient fluid flow. He completed his Masters thesis and graduated in May of 2011.

PhD student Won Joon Song is working with the PI on the seismic anisotropy of faults and shear zones. Won Joon is using SEM-EBSD mineral orientation maps of these rocks as input files for some of his numerical models.

Masters student Benjamin Frieman studied kinematic vorticity in the rocks hosting the shear zone using the SEM-EBSD and numerical modeling. He completed his degree in August 2012 (Frieman, 2012) and is now a Ph.D. student at the Colorado School of Mines.

Undergraduate student Hendrik Lenferink completed his undergraduate honors thesis on the topic of kinematic vorticity in these rocks under Johnson's guidance (Lenferink, 2008), and is now pursuing a PhD at MIT.

Findings:

PhD student Nancy Price?s work on the Sand Hill Corner shear zone focused on characterizing both the transient, coseismic and long-term, interseismic deformation and the relationships between the two, specifically (1) the transformation of pseudotachylyte into ultramylonite through recrystallization and deformation, and (2) the deformation of mono-mineralic quartz ribbons and interpretation of their complex crystallographic preferred orientation (CPO) patterns.

1. Through her work on pseudotachylyte-derived ultramylonites in the Sandhill Corner shear zone, Nancy (a) documented the mineralogical and microstructural changes associated with recrystallization and deformation of pseudotachylyte and from these observations, compiled a list of criteria for identifying deformed pseudotachylyte. Using her criteria, she proposed that a significant majority (>30%) of the ultramylonite layers within the Sandhill Corner shear zone represent deformed pseudotachylyte. This research is globally significant because it suggests that deformed pseudotachylyte may be more prevalent than previously thought in faults exhumed from the base of the seismogenic zone. This research resulted a peer-reviewed paper (Price et al., 2012).

2. Using c-axis CPO patterns derived from mineral orientation maps of mono-mineralic quartz ribbons collected from within the Sandhill Corner shear zone, Nancy (a) identified and isolated the inherited host rock CPO pattern from the shear zone pole figures, (b) proposed how the pole figures evolved with dextral shearing to transform the host fabric into the complex shear fabrics found (including the role of the host rock fabric in facilitating dynamic recrystallization in quartz), and (c) identified microstructural patterns little-documented in the literature that may have been the result of elevated stresses/strain rates during the transient portion of the seismic cycle. This research is of significance to the microstructure research community because it proposes how transient deformation might affect interseismic quartz fabric development in fault zones, an effect that has until recently been unaddressed. A manuscript based on this research will be submitted for publication within

the next 6 months. Nancy is continuing this work (in collaboration with the PI) beyond her dissertation by correlating transient quartz-filled fractures as imaged with cathodoluminescence with the SEM-EBSD derived mineral orientation maps.

Nancy also built maps showing the spatial distribution of rock type, amount of pseudotachylyte and deformed pseudotachylyte, quartz microstructure, and quartz grain sizes within the Sandhill Corner shear zone. From these maps, Nancyproposed an across-strike architecture of a shear zone core rich in deformed pseudotachylyte, an inner shear zone characterized by the finest quartz new grain sizes, and an outer shear zone, which are comparable to the width to the upper crustal principal slip zone, fault core, and damage zone, respectively. This is one of the few studies where such a detailed view of a shear zone from frictional-to-viscous transition depths has been presented. Nancy will continue to work with the PI to build this work into a manuscript for publication.

In addition to Nancy?s dissertation research, undergraduate Hendrik Lenferink and graduate student Ben Frieman have addressed questions of vorticity from rocks collected in and near the Sandhill Corner shear zone. For his undergraduate thesis, Hendrick conducted numerical modeling of lubricated clast rotation across the full range of kinematic vorticity numbers. The implications of this work turned out to be rather large; he showed that the rigid clast rotation method of determining kinematic vorticity is strongly compromised by clast lubrication. Two papers were published from this work (Johnson et al, 2009 a,b).

For his Masters thesis, Ben investigated the rotational component of strain in the shear boundinage of staurolite porphyroblasts in the host rocks of the shear zone using mineral orientation maps and numerical modeling. He found that the mode and distribution of mica minerals affects the rotational behavior of the porphyroblast fragments during shearing. A paper based on this research is in review (Frieman et al., in review).

Training and Development:

The students are gaining research experience by interacting with the PIs and collaborators, and gaining skills on a range of analytical equipment including electron microprobe, SEM-EBSD, XRF, XRD and FTIR. They are also incorporating numerical modeling into their dissertation/thesis work. The undergraduate student received the same opportunities and training.

Outreach Activities:

Journal Publications

Johnson, S.E., "Rotation of porphyroblasts and strain localization: Debate settled!", Geology, p. 663, vol. 37, (2009). Published, 10.1130/G25729A.1

Johnson, S.E., Lenferink, H.J., Price, N.A., Marsh, J.H., Koons, P.O. West, D.P., Jr., and Beane, R., "Clast-based kinematic vorticity gauges: the effects of slip at matrix/clast interfaces.", Journal of Structural Geology, p. 132, vol. 31, (2009). Published, 10.1016/j.jsg.2009.07.008

Johnson, S.E., Marsh, J.H. and Vernon, R.H., "From tonalite to mylonite: coupled mechanical and chemical processes in foliation development and strain localization.", Journal of the Virtual Explorer, p. , vol. 30, (2008). Published, 10.3809/jvirtex.2009.00208

Johnson, S.E., Lenferink, H.J., Marsh, J.H., Koons, P.O. and West, D.P., Jr., "Kinematic vorticity analysis and evolving strength of mylonitic shear zones: new data and numerical results", Geology, p. , vol. 37, (2009). Published, 10.1130/G30227A.1

Johnson, S.E. and Jin, Z.-H., "Magma extraction from the mantle wedge at convergent margins through single and multiple dikes: A parametric sensitivity analysis.", Geochemistry, Geophysics, Geosystems, p. , vol. 10, (2009). Published, 10.1029/2009GC002419

Johnson, S.E., "Reply to Comment: Rotation of porphyroblasts and strain localization: Debate settled!", Geology, p. , vol. 38, (2010). Published, 10.1130/G30835Y.1

Price, N.A., Johnson, S.E., Gerbi, C.C., & D.P. West Jr., "Identifying deformed pseudotachylyte and its influence on the strength and evolution of a crustal shear zone at the base of the seismogenic zone", Tectonophysics, p. , vol. , (2012). Published, 10.1016/j.tecto.2011.11.011

Frieman, Ben M.; Gerbi, Christopher C.; Johnson, Scott E.,, "The effect of microstructural and rheological heterogeneity on porphyroblast kinematics and bulk strength in porphyroblastic schists", Tectonophysics, p. , vol. , (2012). Submitted,

Books or Other One-time Publications

Price, N.A., "Structure and rheology of the Sandhill Corner shear zone, Norumbega fault system, Maine: A study of a fault from the base of the seismogenic zone", (2012). Thesis, Unpublished
Bibliography: University of Maine

Frieman, B., "The Effect of Microstructural and Rheological Heterogeneity on Porphyroblast Kinematics and Bulk Strength in Porphyroblastic Schists", (2012). Thesis, Unpublished
Bibliography: University of Maine

Lenferink, H.J., "Kinematic vorticity and porphyroclast rotation in mylonites of the Norumbega Fault System: Implications for paleoviscometry", (2008). Undergraduate Honors Thesis, Unpublished
Bibliography: University of Maine

Price, N.A.; West, D.P.,Jr.; Johnson, S.E.; & Marsh, J.H., "Coupled deformation and metamorphism, ultramylonite development, and evidence for paleoseismicity during protracted dextral shearing in south-central Maine ", (2010). Field Guide Chapter, Published
Editor(s): Gerbi, C.C.; Yates, M.

Collection: Guidebook for fieldtrips in coastal and interior Maine, 102nd New England Intercollegiate Geological Conference

Bibliography: p. 109-131

Price, N.A.; Johnson, S.E.; Gerbi, C.C.; Koons, P.O., "The structure of a shear zone at the base of the seismogenic zone, Norumbega fault system, Maine", (2012). Conference Abstract, Published
Bibliography: Structural Geology and Tectonic Forum, Williamstown, Massachusetts

Price, N.A.; Johnson, S.E.; & Gerbi, C.C.; Koons, P.O., "Structure of a shear zone at the base of the seismogenic zone, Norumbega fault system, Maine; Potential for comparison with upper-crustal fault structure", (2011). Conference Abstract, Published

Bibliography: American Geophysical Union, Fall
Meeting 2011, T33E-2463.

Price, N.A.; Johnson, S.E.; Gerbi, C.C., "Using heterogeneous quartz CPO
data to interpret the deformation history
of a shear zone at the base of the
seismogenic zone", (2011). Conference Abstract, Published
Bibliography: Geological Society of America Abstracts
with Programs, 43(5), 648

Price, N.A.; Johnson, S.E.; Gerbi, C.C., "The influence of pseudotachylyte
on the strength and evolution of a
crustal shear zone at the base of the
seismogenic zone", (2011). Conference Abstract, Published
Bibliography: Penrose Conference on Deformation
Localization in Rocks: New Advances,
Cadaques & Cap de Creus Peninsula,
Catalonia, Spain.

Price, N.A.; Johnson, S.E.; Gerbi, C.;
Koons, P.O, "The influence of
pseudotachylyte formation and
deformation on bulk rock strength
within a shear zone from the base of the
seismogenic zone", (2010). Conference Abstract, Published
Collection: Geological Society of America Abstracts
with Programs
Bibliography: Vol. 42, No. 5, p. 423.

Price, N.A.; Johnson, S.E.; Koons, P.O., "The Influence of Transient
Structures on the Rheology and Stability
of a Shear Zone from the Base of the
Seismogenic Zone, Norumbega Fault
System, Maine", (2010). Conference Abstract, Published
Bibliography: Gordon Research Conference on Rock
Deformation, Tilton, N.H.

Price, N.; Johnson, S.E.; Gerbi, C.C., "Microstructural Evidence for Strain
Localization at the Frictional-to-Viscous
Transition, Norumbega Fault System,
Maine", (2009). Conference Abstract, Published
Bibliography: American Geophysical Union, Fall
Meeting 2009, T53B-1575

Price, N.A.; Johnson, S.E.; Koons, P.;
Yates, M., "Microstructural record
of coseismic/postseismic cycles near the
base of the seismogenic zone, Sand Hill
Corner Mylonite Zone, Norumbega Fault
System, Maine", (2009). Conference Abstract, Published
Collection: Geological Society of America Abstracts
with Programs
Bibliography: 41(3), 87

Price, N.A.; Johnson, S.E.; Koons, P.;

Seaman, S., "Microstructural
Evidence for Seismic Rupture, Post-
seismic Creep, and Fluid Transport in
the Frictional-to-Viscous Transition,
Norumbega Fault System, Maine, USA", (2008). Conference Abstract, Published
Bibliography: American Geophysical Union, Fall
Meeting 2008, T53C-1963

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

We developed new numerical techniques for evaluating the coupling of viscous flow in shear zones to the frictional flow on an overlying fault.

We developed new criteria for identifying deformed pseudotachylyte in seismogenic fault zones.

We developed new techniques for evaluating complex and ambiguous quartz LPO data.

We are developed new techniques for evaluating the kinematic vorticity number in clast-bearing mylonite zones.

We are developing new techniques for evaluating the strength of clast-bearing mylonite zones.

We are developing new techniques for assessing the effects of fabric development on crustal seismic anisotropy.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

This project is partly supporting the thesis work of 3 PhD students, 2 MS student and 2 undergraduate students.

Contributions to Resources for Research and Education:

In order to contribute to national and international educational and research resources, we have implemented web-based publication of student projects that explore or review fundamental information, concepts and processes in the Earth Sciences. The following URL shows some of the results to date.

http://www.geology.um.maine.edu/geodynamics/analogwebsite/

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Activities and Findings: Any Outreach Activities

Any Web/Internet Site
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Beyond Science and Engineering
Any Conference